ENERGY USE IN THE PRODUCTION OF PRIMARY ZINC

Hanagudu Harish

Virendra S. Kothari

Discussion Paper No. 05/88

Tata Energy Research Institute
7, Jorbagh
New Delhi 110 003

November, 1988

The copyright of this paper lies with the Tata Energy Research Institute. No part of this paper may be quoted, reproduced or utilized in any form, or by any means, without prior permission from the Tata Energy Research Institute, New Delhi.

CONTENTS

Page

List of Tables iii

List of Figures vi

Abstract 1

Key Words 1

1 INTRODUCTION 2

STUDY OBJECTIVES 3

METHODOLOGY 3

REPORT STRUCTURE 4

2 INDUSTRY STATUS 5

BACKGROUND 5

INDUSTRY STRUCTURE 5

PRODUCTION TRENDS 7

DEMAND AND CONSUMPTION PATTERN 12

END USES 19

3 PRODUCTION OF PRIMARY ZINC 22

MINING 22

BENEFICIATION 28

SMELTING 30

Roasting 32

Leaching 35

Purification 39

Electrolysis 40

Melting 45

Residue Treatment Plant (RTP) 45

COMBINED MATERIAL AND ENERGY BALANCE 48

4 COMPARISON OF MATERIALS AND ENERGY USE BETWEEN INDIAN AND INTERNATIONAL PLANTS 52

5. FUTURE DEVELOPMENTS 57

PROCESS ROUTE COMPARISON 57

TECHNOLOGY COMPARISON 58

Flexibility 58

Metal Recovery 58

Investment 59

Energy Consumption 59

Appendix - 1 Thermal Conversion Values of Different Forms of Energy 62

References 63

LIST OF TABLES

No. Page

1 Location and Installed Capacities of Zinc Smelters 6

2 Capacity of Zinc-Lead Ore Mines in India 8

3 Zinc Industry: Trend in Installed Capacity, Production and Capacity Utilization 10

4 Trend in Production and Capacity Utilization of Primary Zinc Smelters in India 13

5 Zinc Industry: Production and Imports 14

6 Zinc: Level of Demand Satisfaction by Indigenous Production 16

7 Demand Projection of Zinc 18

8 Gap in Future Demand and Production of Zinc 18

9 Comparison of Per Capita Consumption of Zinc 20

10 Location of Operating and Proposed Zinc-Lead Mines in India 24

11 Energy Consumption in Mining of Ore, 1978-79 25

12 Break-up of Installed Capacity of Electrical Equipment in the Mochia Mines, 1979-80 25

13 Production of Zinc Concentrate, 1980-84 27

contd....

LIST OF TABLES (contd.)

No. Page

14 Electrical Energy Use in Beneficiation at Mochia and Balaria Concentrators 31

15 Roaster Section: Material and Energy Requirements 34

16 Sulphuric Acid Plant: Material and Energy Requirements. 36

17 Leaching and Purification: Material and Energy Requirements 39

18 Electrolysis Plant: Material and Energy Requirements .. 42

19 Cathode Melting: Material and Energy Requirements 42

20 Residue Treatment Plant HZL-Vizag: Energy and Material Requirements 46

21 Energy Consumption in the Production of Zinc 49

22 Electrical Energy Use in Indian and Internatioal Zinc Plants 54

23 Comparison of Material Consumption in Indian and Australian Zinc Plants 55

24 Specific Energy Consumption - Electrolytic Zinc Route Products: 1 t SHG Zinc, 1.78 t H_2SO_4 (net) 60

contd...

LIST OF TABLES (contd.)

No. Page

25 Specific Energy Consumption - Imperial Smelting Process Route Products: 1 t SHG zinc, 0.5 t lead, 2 t H_2SO_4 61

LIST OF FIGURES

Fig No. Page

1 Trend in Capacity Utilization 9

2 Sectoral Consumption of Zinc in Industry, 1984-85 17

3 Process Block Diagram for Zinc Smelting 29

4 Material Flow for 1 t of Zinc Ingot at HZL Smelter - Vizag 43

5 Material Flow for 1 t of Zinc Ingot at HZL Smelter - Debari 44

6 Outline Flowsheets for EZ and ISP Routes of Zinc Production 53

ABSTRACT

Zinc is one of the major basic metals. Energy and materials account for as much as 70% of the total cost of primary zinc production in India, hence conservation of these two components would contribute much to savings in the overall cost of production. This paper analyzes the consumption of energy and materials in the primary zinc industry, specifically the Debari and Visakhapatnam plants of Hindustan Zinc Limited (HZL). While describing the steps involved in the production of primary zinc, energy and materials required in each step are estimated and compared between the plants. Factors which result in higher energy requirements are indicated. Areas where energy savings are possible are examined, and measures for reducing energy requirements are suggested.

Energy and materials consumption in Indian plants and international plants (USA & Australia) are compared, and the reasons for higher energy consumption in Indian plants are indicated. Future plans for primary zinc production in India are described, and a comparison of the Electrolytic Zinc Process (EZP) with the Imperial Smelting Process (ISP) (being adopted for future capacity) is given.

KEY WORDS : Zinc, Smelters, Pyrometallurgy, Electrometallurgy, Energy conservation, Energy consumption.

1. INTRODUCTION

Zinc ranks fourth among all metals in the total world production. Only iron, aluminium and copper exceed it.

Pure freshly polished zinc is bluish white, lustrous, and moderately hard. Moisture in the air brings about a superficial tarnishing to give the metal its usual grayish colour. Zinc is a fairly good conductor of heat and electricity. However, its electrical resistivity is almost four times that of silver - the best electrical conductor. Likewise, as a conductor of heat, it is only about one fourth as efficient as silver. Pure zinc is malleable and ductile enough to be rolled or drawn, but small amounts of other metals present as contaminants may render it brittle.

The process of producing zinc from the ore is power intensive. It is estimated that around 5,000 kWh of electricity is consumed in producing one tonne of zinc ingot from the ore (smelting). About 80 per cent of this energy is consumed in the electrolysis process. Power is a critical input; stable and adequate power supply is hence essential for the proper operation of the smelters. Other forms of energy used include light diesel oil, fuel oil, coke and coke breeze.

It is estimated that major inputs like energy and raw materials form nearly 70 per cent of total production costs. Energy and materials are hence critical components in the production of zinc. Conservation of energy and materials would go a long way in reducing the overall cost of production.

STUDY OBJECTIVES

- To understand and estimate energy use in the production of primary zinc.
- To estimate the consumption of raw materials and energy at each stage of zinc production.
- To compare the use of energy and raw materials among the primary zinc producers
- To compare energy and materials consumption and energy intensity of Indian plants with the international plants.

METHODOLOGY

Keeping with the above objectives, a questionnaire was prepared seeking specific information on energy and materials consumption. The information sought was for a period of five years, and included annual consumption of raw materials and energy forms for the different process sections of the plant; operating characteristics of energy consuming equipment like boilers, furnaces, cell house etc.; and details of energy conservation measures adopted or planned for the plant.

The questionnaire was mailed to all the three primary zinc producing smelters in the country,viz., Hindustan Zinc Limited (HZL) in Debari and Visakapatnam, and Cominco Binani Zinc Ltd (CBZ) in Binanipuram. The response to the questionnaire was fairly good. Of the three, HZL - Debari; and HZL - Visakapatnam replied to the questionnaire. The research team visited the plants and held discussions with the plant personnel to obtain details and clarifications.

In addition, data available from other sources were also used for the purpose of analysis.

REPORT STRUCTURE

This report has been divided into four chapters.

The chapter following the introduction gives the status of zinc industry. The evolution and growth of the industry as well as past trends in production and consumption of zinc are described. The future demand for zinc and the different end uses of zinc are also discussed.

Chapter 3 deals with the energy and materials use in the production of zinc: the different steps involved in zinc production are explained. The energy and material flows in each of these steps have been estimated and a comparison between plants has been given.

A comparison of the performance of primary zinc producing units in India and in other countries is carried out in Chapter 4.

Chapter 5 discusses future technology trends and developments in the industry.

2. INDUSTRY STATUS

BACKGROUND

The origin of zinc industry in India has a 2500-year-old history. Radio-carbon dating of wood and charcoal samples obtained from the ancient mines of Zawar and Rajpur-Dariba in Rajastan, indicate that mining and smelting of zinc were done as far back as 500 BC [5]. The industry flourished during the medieval period, but went into oblivion in the 19th Century. After the World War II, the industry was revived on a small scale, and a major effort to establish modern facilities was initiated in the sixties.

INDUSTRY STRUCTURE

Two companies account for the entire production of primary zinc in India. These are; Hindustan Zinc Limited (HZL), a public sector company operating mining, concentration, and smelting facilities, and Cominco Binani Zinc Limited (CBZ), a private sector company involved in smelting operations.

HZL operates smelting plants at two locations; Debari in Rajastan, and Visakhapatnam in Andhra Pradesh. The Debari plant was commissioned in 1960, with a production of 10,000 t/yr of zinc. Production was based on concentrates obtained from the Zawar mines. The plant was expanded to 45,000 t/yr in 1976-77, and later to 49,000 t/yr in 1983-84 by installing a leach-residue-treatment-plant based on the well known Outokompu process. The Visakhapatnam (Vizag) smelter

Table 1 : Location and Installed Capacities of Zinc Smelters

Company	Location	Installed Capacity (t/yr)
Hindustan Zinc Limited (HZL)	Debari (Rajasthan)	49,000
	Visakhapatnam (Andhra Pradesh)	30,000
Comminco Binani Zinc Limited (CBZ)	Binanipuram (Kerala)	14,000
TOTAL		93,000

Source : 1. Department of Mines, Ministry of Steel and Mines, Government of India , _Annual Report_ - _1983-84_, New Delhi, 1984.

2. National Council of Applied Economic Research, _Forward and Backward Linkages in Non-Ferrous Metals and Coal and Lignite Sectors, Vol. 1 - Lead, Zinc and Cadmium_, New Delhi, 1983.

was commissioned in 1977, with an annual capacity of 30,000 t and is based mainly on imported concentrate. HZL also produces lead, silver, cadmium and by-product sulphuric acid.

CBZ's smelter at Binanipuram in Kerala, commissioned in 1967, is also based on imported concentrate with a capacity of 14,000 t/yr. The location and the installed capacities of these smelters are shown in Table 1.

Indigenous zinc ore occurs in the form of zinc-lead deposits with 95 per cent of the ore reserves located in South Rajastan. The major operating mines are the Zawar group comprising of Mochia and Balaria mines, each having a capacity of 2,000 t/day of ore and the Rajpura-Dariba mines which have a capacity of 3,000 t/day. Both are underground mines; while the Zawar mines contain low grade deposits amenable to simple beneficiation techniques, the Rajpura-Dariba mines contain high grade ore having complex mineralogy and require sophisticated metallurgical processing techniques. The run-of-mine ore is processed in concentrators associated with the mines to produce both zinc and lead concentrates.

Table 2 gives the location and capacity of mines producing zinc-lead ore in the country.

PRODUCTION TRENDS

The production of zinc in the country for the years 1980-1986 is shown in Table 3, and the trend in capacity utilization is illustrated graphically in Fig 1. It is observed from the graph that capacity utilization of the primary zinc smelters has never been very high.

Table 2 : Capacity of Zinc-Lead Ore Mines

Mines	Capacity (t/day zinc-lead ore)
Rajpura-Dariba (Rajasthan)	3,000
Zawar Group (Rajasthan)	
- Balaria	2,000
- Mochia	2,000
- Zawarmala	600
Sargipalli (Orissa)	500
Agnigundala (Andhra Pradesh)	240
Rangpo (Sikkim)	100
TOTAL	8,440

Source : Kapur R.P., "Development of Lead-Zinc Mining in India", *Urja*, November, 1984, p. 395.

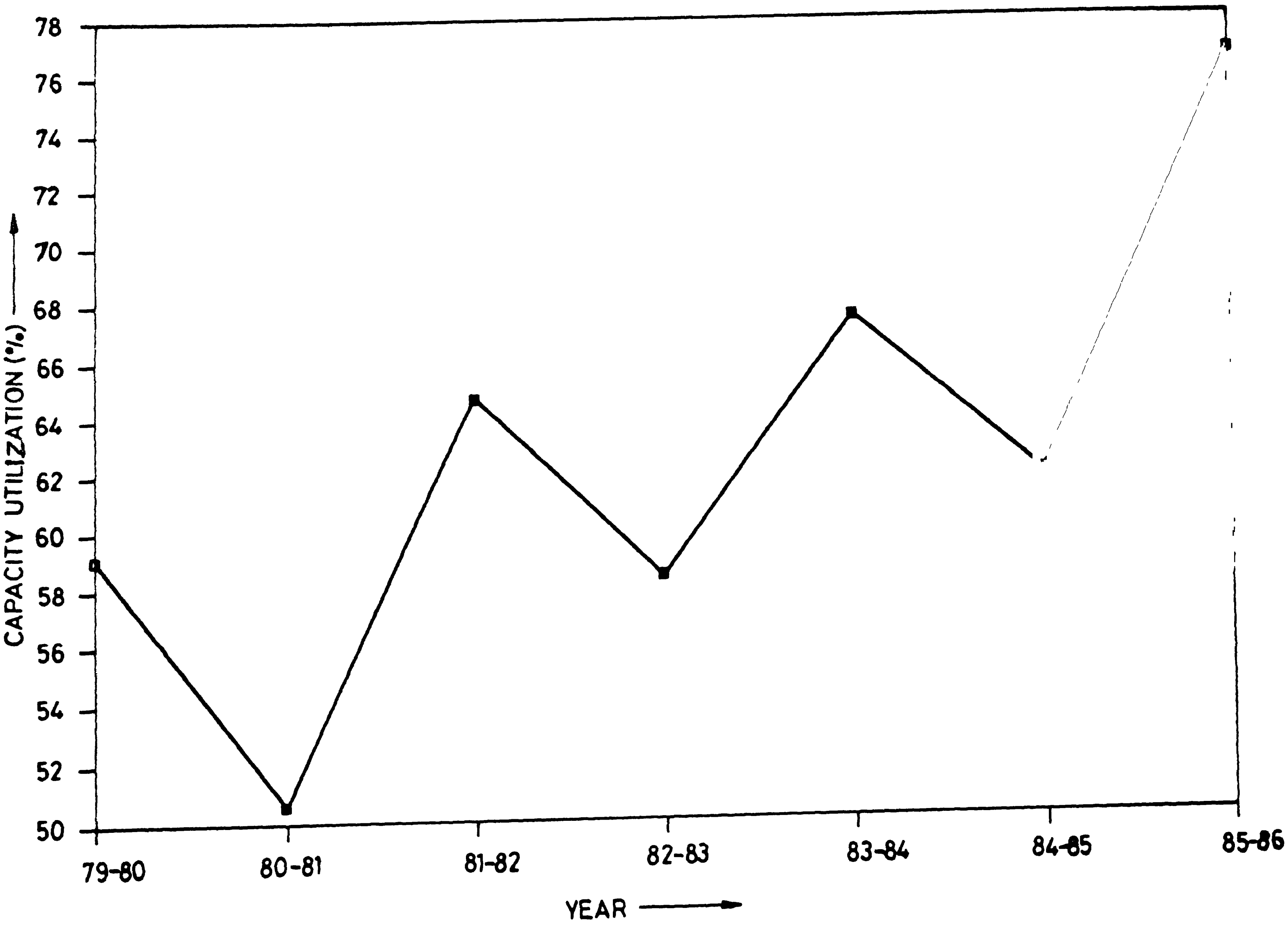

FIG. 1 - TREND IN CAPACITY UTILIZATION

Table 3 : Zinc Industry : Trend in Installed Capacity, Production, and Capacity Utilization

Year	Installed Capacity (t/yr)	Production[1/] (t)	Capacity Utilization (per cent)
1979-80	89,000	52,600	59.1
1980-81	89,000	45,000	50.5
1981-82	89,000	57,600	64.7
1982-83	89,000	51,900	58.3
1983-84	89,000	60,100	67.5
1984-85	93,000	57,600	61.9
1985-86	93,000	71,400	76.7

1/ Production figures rounded to the nearest hundred tonnes

Source : Minerals and Metal Review , Annual Review, 1986, p. 125.

Production has suffered due to several reasons which mainly include shortage of power, problems in availability of raw material concentrate, operational bottlenecks, overaged plant and equipment etc.

The performance of each of the individual primary zinc smelters is shown in Table 4. Production at the Debari smelter has suffered in the past few years mainly due to the shortage of power and poor operational performance of the newly commissioned treatment facilities. To ensure adequate power availability for the smelters, gas turbine power generating sets are being installed at Debari. The Vizag smelter based on imported concentrate has performed relatively better, although strained labour relations had affected production marginally. The two smelters of HZL which account for over 90 per cent of the total zinc production in the country, however have shown record outputs for the year 1985-86, achieving 100 per cent of the annual targets. Zinc production at both the smelters at Debari and Vizag has been the highest in 1985-86 compared to any other year.

Recent improvements in the performance of these units is mainly attributed to system changes in different operational areas, which include the following :

- technical improvements in stabilising the new purification system at Debari
- improved performance of the newly commissioned residue treatment facility at Debari
- better power availability at both Debari and Vizag, and
- energy conservation measures adopted at both the smelters.

The capacity utilization of the sole private sector unit - CBZ, has been low throughout. Ever since it went into production in the late sixties, the unit has not been able to achieve its licenced capacity due to design snags and other problems such as shortage of imported zinc concentrate and inadequate power availability. Capacity utilization has been as low as less than 50 per cent in the years 1983-84 and 1984-85. There was a slump in output when the company had stopped operation in March 1984 due to shortages of power and imported zinc concentrate. Production however, is reviving since 1986 as there has been an improvement in the power situation. Steps to raise its production capacity to the original licenced capacity of 20,000 t/yr have been completed recently.

DEMAND AND CONSUMPTION PATTERNS

The country's demand for zinc, which was met entirely through imports in the early post-independence period, has grown from 25,100 t in 1950 to 1,25,000 t in 1983-84. At present, indigenous production—in the existing six lead-zinc mines with an ore production capacity of 8,440 t/day and in the three smelters with a capacity of 93,000 t/yr of zinc—is unable to meet the demand: the gap is bridged by imports.

The domestic requirements of zinc are met by production of primary zinc through both indigenous and imported concentrate, by importing the metal by the Minerals and Metals Trading Corporation (MMTC), and directly by the end users. Table 5 gives the break-up of zinc supply through production and imports for the last few years.

Table 4 Trend in Production and Capacity Utilization of

Primary Zinc Smelters in India

Year	HZL, Debari[1]		HZL, Vizag[2]		Cominco Binani[3]	
	Production (t)	Capacity Utilization (per cent)	Production (t)	Capacity Utilization (per cent)	Production (t)	Capacity Utilization (per cent)
1978-79	28,000	62 2	21,900	73 0	NA	-
1979-80	27,200	60 4	17,200	57 3	NA	-
1980-81	22,300	49 5	22,200	74 0	1,000	7 0
1981-82	23,200	51 5	23,300	77 6	11,100	79 2
1982-83	19,200	42 6	24,200	80 6	8,300	59 1
1983-84	32,500	66 3	NA	-	6,400	45 7
1984-85	NA[4]	-	NA	-	6,800	48 5
1985-86	35,000	71 4	25,100	83 6	11,400	81 4

Note . Production figures rounded off to the nearest hundred tonnes

1/ Installed capacity at HZL-Debari smelter was stepped up from 45,000 t/yr to 49,000 t/yr in 1983-84

2/ Installed capacity at HZL-Vizag smelter - 30,000 t/yr

3/ Installed capacity at CBZ smelter - 14,000 t/yr

4/ Not Available

Source . 1. Study questionnaire responses

2. National Council of Applied Economic Research , *Forward and Backward linkages in Non-Ferrous Metals and Coal and Lignite Sectors, Vol. 1 - Lead, Zinc and Cadmium*, New Delhi,1983

3. Minerals and Metal Review, *Annual Review*, 1986, p. 125.

Table 5: Zinc Industry : Production and Imports[1/]

(t)

Year	Production	Imports	
		MMTC[2/]	Direct by End-Users
1982-83	51,900	70,000	16,000
1983-84	60,100	54,000	18,500
1984-85	57,600	56,900	15,000
1985-86	71,400	55,000	18,000

1/ Numbers rounded to the nearest hundred t

2/ Minerals and Metals Trading Corporation

Source : Lead Zinc Information Centre, Annual Report,
New Delhi. Various issues.

Zinc demand has always outstripped supply from indigenous production, which on an average has been able to meet around 50 per cent of the demand. The level of demand satisfaction for the last few years is indicated in Table 6.

The Seventh Plan growth rate for zinc consumption is estimated as 4.5 per cent. For the period 1990/91 - 2000/01, the compound growth rate is estimated to be 4 per cent. The Working Group on Non-Ferrous Metals constituted by the Planning Commission has projected demand to rise to 1,69,300 t in 1990/91 and 2,50,600 t in 2000/2001. Demand for zinc till the year 2000 is shown in Table 7. Based on these figures, the gap between supply and demand till the year 1995-96 is projected in Table 8.

The level of demand satisfaction shown in Table 8 is without any smelter addition. It is seen from the table that zinc production from the existing capacity can meet only around 50 per cent of the total demand in 1994/95, and this number falls to approximately 40 per cent by the turn of this century. This would lead to an increased outflow of foreign exchange for the import of zinc.

To meet a substantial portion of the future demand of zinc, a new lead-zinc smelter at Chanderiya in Rajastan of capacity 70,000 t/yr of zinc and 35,000 t/yr of lead is being set up. Production capacities of the mining facilities would also increase considerably after the implementation of several proposals currently under consideration. Among the major projects are the development of new mines at Rampura-Agucha and Baroi, both in Rajastan, of capacity 2,500 t/day and 1,000 t/day respectively.

Table 6: Zinc : Level of Demand Satisfaction by Indigenous Production

Year	Production[1/] (t)	Consumption[2/] (t)	Level of Demand Satisfaction (per cent)
1975-76	-	67,000	-
1979-80	52,600	106,000	49.6
1980-81	45,000	94,000	47.3
1981-82	57,600	113,000	50.9
1982-83	51,900	100,000	51.9
1983-84	60,100	120,000	50.0
1984-85	57,600	125,000	46.0
1985-86	71,400	130,000	54.9

1/ Production figures rounded to the nearest hundred t

2/ Computed on the basis of sales by HZL, CBZ, MMTC, REP imports

Source : Minerals and Metals Review , "Lead-Zinc, Push for Self Sufficiency Now", January, 1987.

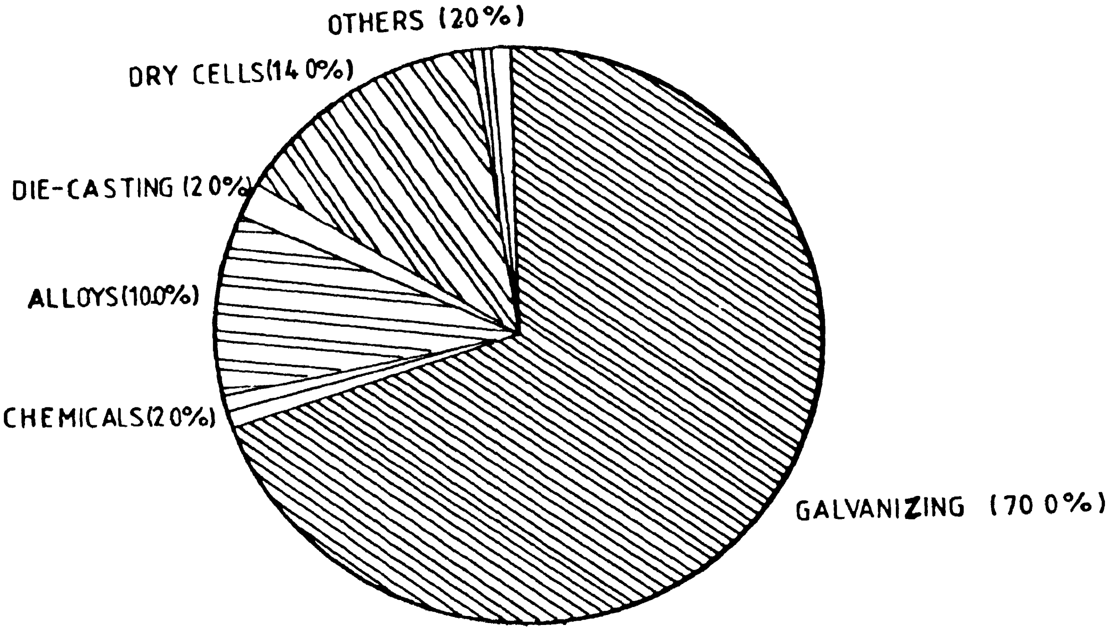

FIG. 2-- Sectoral Consumption of Zinc in Industry, 84-85

Source Compiled from Pugazhenthy, L (1985) Status of Secondary Zinc Industry in India

Table 7: Demand Projection of Zinc

Year	Demand (t/yr)
1985-86	136,500
1990-91	169,300
1995-96	206,000
2000-01	250,600

Source : Kapur, R.P. "Development of Lead-Zinc Mining Industry in India", Urja, November, 1987.

Table 8. Gap in Future Demand and Production of Zinc

Years	Demand (t)	Production (t)	Gap in Demand and Supply (t)	Demand Satisfaction[1/] (per cent)
1989-90	162,800	99,000	63,800	60.8
1994-95	198,100	99,000	99,100	50.0
1999-2000	241,000	99,000	142,000	41.1

1/ Level of demand satisfaction is without any smelter addition

Source: "The Production Scene", Minerals and Metals Review, January, 1987, 21-26.

The per capita consumption of zinc in India is extremely low as compared to other countries in the world. Table 9 shows India's position today. The report of the National Council of Applied Economic Research estimates that the per capita consumption of zinc would go up to 0.281 Kg by the year 2000, which will be a little higher than China's present per capita consumption.

END USES

The most important uses of zinc are as a protective coating on other metals and for its alloys. The consumption of zinc in the different secondary sectors for the year 1984-85 is illustrated in Figure 2.

Coating iron or steel with zinc, a process called galvanizing, accounts for nearly 70 per cent of the primary zinc used in various industries in India [10]. The physical presence of the zinc coat prevents corrosion of iron, and even if breaks in the coat expose iron, the greater chemical activity of zinc causes it to be consumed in preference to iron.

Consumption of zinc in the galvanizing industry in India would continue to grow further as industrialization progresses. Many substitutes for zinc galvanizing have been tried but with limited success. The galvanizing industry has four prominent sub-divisions. Among them, tube galvanizing is the major section, forming nearly 61 per cent of this industry. Other important sub-divisions include sheet galvanizing (18 per cent), wire galvanising (8 per cent), and structural galvanizing (8 per cent) [7].

Table 9: Comparison of Per Capita Consumption of Zinc

Country	Zinc consumption per capita (kg)
West Germany	7.120
U.S.A	3.690
Republic of Korea	2.120
China	0.202
India	0.158

Source : National Council of Applied Economic Research Forward and Backward Linkages in Non - Ferrous Metals and Coal and Lignite Sectors, Vol. 1 - Lead, Zinc and Cadmium, New Delhi,1983..

Dry cells or batteries constitute the next major consumer of zinc. About 95 per cent of the production of dry batteries is of the ordinary type used for torches and transistors. This accounts for about 14 per cent of total zinc consumption.

The alloy industry uses zinc mainly to produce brass and other copper and zinc based alloys.

Die casting of zinc is by and large for automobile parts. In die casting, aluminium has begun to substitute zinc but adoption of thin-wall technology in zinc die casting is likely to check this trend.

Zinc oxide is consumed in rubber industry where it finds application as an accelerator in vulcanization. Other uses of zinc oxide are in paint, ceramic, textile and chemical industries.

A major share of the zinc dust produced, nearly 65 - 80 per cent, is consumed to manufacture sodium hydrosulphite, which is used as a bleaching and reducing agent in textile finishing and dyeing. The rest of it finds use in pigment, rayon, and pesticide industries.

3. PRODUCTION OF PRIMARY ZINC

Zinc is produced by three processes; two pyrolytic and one electrolytic. In India, however, the entire production of zinc is by electrolytic process.

Recovery of zinc by electrolytic means has advantages over pyrolytic methods; of being more amenable to the treatment of lower grade concentrates and to the recovery of by-products, and the elimination of dust and heat of furnaces other than roasters. The electrolytic zinc plant however has a higher capital cost which is an adverse factor. The electrolytic zinc process has the advantage of directly producing special high grade zinc which is used for die casting. Zinc from pyrolytic plants is normally somewhat less pure.

The three major steps in the production of primary zinc are :

- Mining of the ore
- Beneficiation of the ore to obtain zinc concentrate and
- Smelting of the concentrate to obtain zinc ingots

MINING

In nature zinc-lead deposits occur together. Galena (lead sulphate), sphalerite (zinc sulphide), and rock phosphate are the main minerals worked from these strata bound deposits. Mining of ore could be distinctly different, based on geological factors and natural conditions prevailing within the ore body. There are principally two types of deposits—the strati-form massive complex sulphide deposits and strata-bound vein type deposits. The former contain high grade ore but have complex mineralogy and require sophisticated metallurgical technology for their processing as in the Rajpura-Dariba, Rampura-Agucha, Ambamata and Deri mines. The latter group are low grade deposits amenable to simple beneficiation techniques and are represented by Zawar and Agnigundala set of mines [5].

Table 10 shows the location of the existing mines, and of those that are being developed. The method of mining employed and the corresponding production capacities are also indicated.

Ore bodies in Zawar and Rampura-Agucha have conditions favourable for mechanised mining. Ground conditions in Rajpura-Dariba are weaker which has necessitated the adoption of cut and fill method of mining which is comparatively more expensive. Except for the recent find of Rampura-Agucha which is amenable to open cast mining, the rest of the deposits are steep dipping, narrow, lenticular ore bodies small in size, which require capital intensive underground mining techniques and also long gestation periods [5].

The metal content of Indian ore, extracted both by underground mining techniques and the cut and fill method, varies between 0.84 - 1.55 per cent of lead and 3.36 - 4.17 per cent of zinc [3].

The ore from the stopes is loaded on to granbys through pnuematic chutes and hauled by diesel or electric locomotives, crushed underground and then hoisted through friction winders or belt conveyors. Mining of zinc ore is an energy intensive process since large amounts of zinc ore must be handled to produce relatively small quantities of the concentrate. The major energy requirement in mining is electricity. Electricity is required to power most of the

Table 10: Location of Operating and Proposed Zinc-Lead Mines in India

Mine		Owner	Type	Production Capacity		
				Ore (t/day)	Zinc[1/] (t/year)	Lead[1/] (t/year)
Operating						
Zawar group	(Rajasthan)	HZL[2/]	Underground	4,600	34,000	12,000
Rajpura-Dariba	(Rajasthan)	HZL	Underground	3,000	42,000	11,200
Sargipalli	(Orissa)	HZL	Underground	500	-	6,400
Agnigundala	(Andhra Pradesh)	HZL	Underground	240	-	2,900
Rangpo	(Sikkim)	SMC[3/]	Underground	100	160	50
TOTAL				8,440	76,160	32,500
Under Consideration						
Rampura-Agucha	(Rajasthan)	HZL	Opencast	2,500	68,000	6,600
Ambamata	(Gujarat)	GMDC[4/]	Opencast	1,200	14,400	9,100
Baroi	(Rajasthan)	HZL	Underground	1,000	2,000	7,900
Deri	(Rajasthan)	RSMDC[5/]	Underground	100	1,770	1,200
TOTAL				4,800	86,170	24,800

1/ Recoverable metal

2/ Hindustan Zinc Limited

3/ Sikkim Mining Corporation

4/ Gujarat Mineral Development Corporation

5/ Rajasthan State Mineral Development Corporation

Source : Kapur, R.P. , "Development of Lead-Zinc Mining in India", Urja, November, 1984, p. 395.

Table 11: Energy Consumption in Mining of Ore, 1978-79

Energy	Unit	Unit/t of ore extracted	
		Mochia Mine	Balaria Mine
Electricity	kWh	17.6	18.4

Source : National Council of Applied Economic Research , _Forward and Backward Linkages in Non-Ferrous Metals and Coal and Lignite sectors, Vol. 1 - Lead, Zinc and Cadmium_, New Delhi, 1983.

Table 12: Break-Up of Installed Power Capacity of Electrical Equipment in Mochia Mines, 1979-80

Equipment/Section	Electrical Power Installed Capacity[1/] per cent
Face equipment (Drilling machines, face loaders etc.)	21
Underground transport (Trolleys, conveyors etc.)	3
Winding equipment (Cage winders, winch etc.)	7
Ventilation equipment (Main and auxiliary ventilators)	12
Pumping equipment (Pumpsets for surface and sub-surface)	5
Compressors	5
Others (Crushers, electric overhead cranes, power hammers, feeders etc.)	47

1/ Total installed power capacity is 9438 hp

Source : Estimated from National Council of Applied Economic Research _Forward and Backward Linkages in Non-Ferrous Metals and Coal and Lignite Sectors, Vol. 1 - Lead, Zinc and Cadmium_, New Delhi, 1983.

critical drives. The demand for electricity is partly met by supply from the grid while the deficit is satisfied by captive diesel powered generator sets. The electricity consumption figures of two underground mines in the Zawar belt, each of 2,000 t/day capacity, is shown in Table 11. Energy consumption varies from mine to mine and also within mines of the same capacity essentially due to differences in geological factors and other natural conditions.

Since operating energy consumption data for the mining equipment is not available, installed horsepower of the equipment in the various sections of the Mochia mines is given in Table 12 to indicate the power consumption in the process. It can be seen that the face equipment, essentially comprising of different drilling machines, loaders and shovels are large consumers of electricity. The ventilating equipment which ensure that an adequate level of fresh air is maintained in the mines, are also significant consumers of electrical energy. Air compressors are used to operate pnuematically driven mining equipment or in some instances for loading, hauling and dumping equipment in ore transportation.

Since zinc is mined mostly underground, there are two factors which will have the effect of increasing energy requirements. Safety regulations will require more material for supports etc., which will in turn, add to the need for energy embodied raw materials like steel, cement etc., and increasing labour costs will lead to more mechanization which in turn increase energy consumption.

Table 13: Production of Zinc Concentrate, 1980-84[1/]

(t)

Year	Zinc Concentrate
1980-81	46,500
1981-82	52,900
1982-83	52,800
1983-84	75,600
1984-85	93,000

1/ Rounded off to the nearest hundred tonnes

Source : Department of Mines, Ministry of Steel and Mines, Government of India , _Annual Report - 1983-84_, New Delhi, 1984.

BENEFICIATION

Beneficiation or milling and concentrating of the ore is performed near the mine site to minimise energy consumed in transporting large quantities of ore. The ore arriving from the mines undergoes secondary and tertiary crushing after which it is drawn through disc-feeders and later wet-ground in ball mills in a closed - circuit with hydro-cyclones. Differential froth floatation is carried out to obtain lead and zinc concentrates which are recovered sequentially. Typically in this process, the zinc content is increased from 3-4 per cent present in the run-of-mine ore to 50-52 per cent in the concentrate.

The working performance of the beneficiation plant depends upon several factors including :

- metal content of the ore and the impurities present
- metal content to be obtained in the concentrate and percentage recovery of metals aimed at and
- throughput capacity of the concentrators

Table 13 gives the total production data for zinc concentrate from various mine concentrators for the period 1980-84. Electricity again is the major energy form consumed in the beneficiation process.

Typical electrical energy consumption in kWh/t of ore--treated for the different operations in the beneficiation plant--at the Mochia and Balaria concentrators of the Zawar group of mines is shown in Table 14. The consumption of power varies from 27.5 to 29.5 kWh/t of ore treated [7].

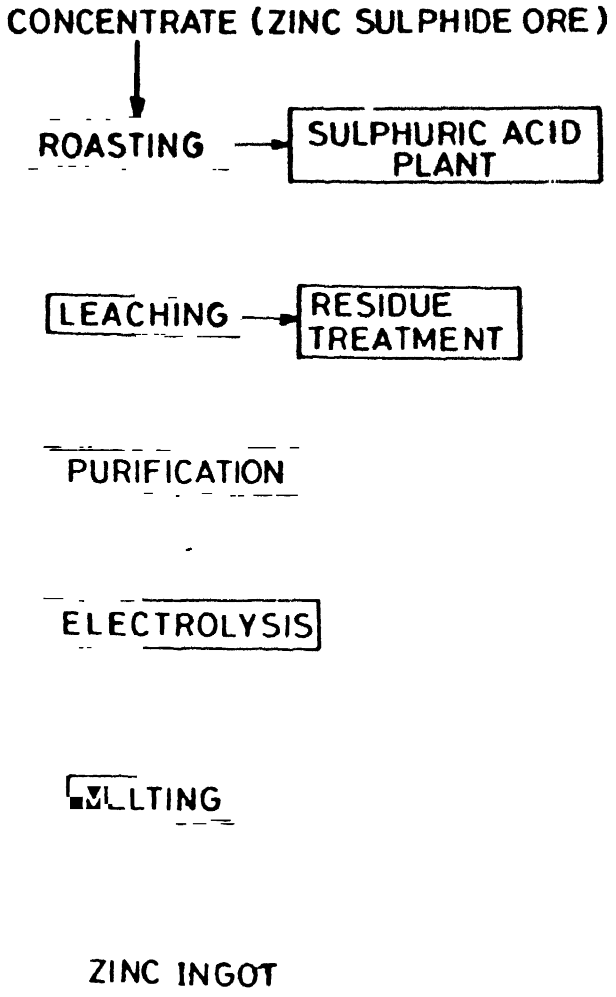

FIG 3 - Process Block Diagram for Zinc Smelting

In the concentration of zinc ores, most of the energy used is mechanical i.e., the energy required to break down the ore to the fineness required for floatation. It is seen from the previous table that crushing and grinding of the ore combined together, account for as much as 65 per cent of the total energy consumed in the beneficiation process. Better control of grinding process would reduce energy requirements in two ways: (i) over-grinding is avoided and (ii) efficiency of floatation will be improved because of accurate sizing of the feed into the floatation machines. Floatation has a high efficiency only within a relatively narrow range of particle size distribution. Autogenous grinding mills, vibration milling, use of rubber lined mills in place of steel, and integrated automated control of concentration operations are all areas whereby relatively major energy savings are possible in the beneficiation process [2].

SMELTING

The zinc smelting process has two routes -- the hydrometallurgical electrolytic route and the pyrometallurgical route. In India, entire zinc production is by electrolytic process; the two pyrolytic processes — electrothermic and vertical retort — are not prevalent .

Smelting involves conversion of the zinc sulphide ore into zinc metal, through a number of physical and chemical steps. The major process operations involved in the hydrometallurgical electrolytic route are schematically shown in Fig 3. These comprise of:

- Roasting, and sulphuric acid production
- Leaching

Table 14: Electrical Energy Use in Beneficiation at Mochia and Balaria Concentrators

Section	kWh/t of ore treated	Percentage of total electrical energy consume
Crushing	4.0	13
Grinding and Classifying	15.0	51
Conditioning, Floatation & Pumping	7.4	25
Thickening and Filtration	1.5	5
Tailings Disposal	1.6	6
TOTAL	29.5	100

Source : National Council of Applied Economic Research , Forward and Backward Linkages in Non-Ferrous Metals and Coal and Lignit Sectors, Vol. 1 - Lead, Zinc and Cadmium, New Delhi, 1983.

- Purification
- Electrolysis
- Melting
- Residue Treatment

Apart from giving a brief description of each of these processes, the corresponding material and energy requirements are discussed in the following sections.

Roasting

In the roasting step, zinc sulphide concentrate containing about 50-52 per cent zinc is converted to zinc oxide by heating and burning with oxygen. This is accomplished in fluidised-bed roasters. The zinc sulphide concentrate fed to the roaster is kept in a fluidised state by a stream of pressurised combustion air admitted through small holes in a steel plate at the base of the vessel. Oxygen in the air reacts with zinc sulphide at a temperature of 1000°C to produce zinc oxide and sulphur dioxide. The principal roasting reaction is as follows:

$$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$$

This reaction is exothermic, and the heat produced supplies the entire energy requirements of the process. External fuel inputs like light diesel oil (LDO) are required only during start-up to bring the roaster to reaction temperature and also occasionally for stabilising roaster reaction conditions.

The hot calcine (zinc oxide product) from the roaster flows through over-flow and under-flow ports to screw the conveyors. The conveyors are provided with water cooling jackets. A recirculating stream of water flowing through the jackets cools the calcine from 900°C to about 150°C. The screws transport the calcine to a series of chain conveyors which feed the material into storage kilns.

Hot gases from the roaster which contain about 6-7 percent sulphur dioxide, are treated to recover sulphur in the form of sulphuric acid. The gases first pass through a waste heat boiler in which steam is generated, and the temperature comes down from 950-1000°C to around 350°C. The steam generated in the waste heat boiler is used to supply heat in the subsequent leaching and purification sections. The gases are cleaned in cyclones and an electrostatic precipitator, followed by scrubbing and cooling to about 30°C, and then sent to the sulphuric acid plant.

Table 15 gives the material and energy balance for the roaster section of two zinc smelters in the country. It is seen from the table that the figures for both these smelters are fairly comparable. The small differences could be attributed to variations in the raw material ore, the number of start-ups etc. All these factors affect energy consumption marginally.

Sulphuric Acid Plant: The high sulphur dioxide (SO_2) roaster off-gases, after passing through the waste heat boiler and gas cleaning equipment, enter a DCDA (Double Contact Double Absorption) sulphuric acid plant. SO_2 gases are converted to sulphur trioxide (SO_3) in a four pass converter, and represented by the following exothermic reaction:

Table 15: Roaster Section : Material and Energy Requirements

Item consumed	Unit	Unit/t of output (calcine)	
		HZL-Vizag[1]	HZL-Debari[2]
Concentrate	t	1.13	1.10
Electrical Energy	kWh	74.00	70.00
LDO for Start-up	l	11.00	10.50
Steam generated in waste heat boiler[3]	t	NA[4]	1.18

1/ Based on average of consumption figures for 1983-85

2/ Based on average annual consumption figures for 1979-83

3/ Waste heat boiler rated at 42 kgf/cm^2 & 10.5 t/h at Vizag and 40 kgf/cm^2 and 10 t/h at Debari

4/ Not Available

Source : Study questionnaire responses

$$SO_2 + 1/2\ O_2 \text{ ---> } SO_3$$

In most of the plants, the cold sulphur dioxide feed gas temperature is increased by exchange of heat with the hot SO_3 gas. This energy transfer occurs in tubular heat exchangers connected to the pass outlets of the converter. In addition to feed heating, this also assists in controlling the equilibrium of the reversible chemical reaction occuring in the formation of SO_3 by withdrawing the hot SO_3 gases after they reach a temperature of around 600°C.

The converter gases then pass through an absorption tower in which concentrated sulphuric acid is circulated, counter current to the flow of gases. The acid is further cooled to 70-80°C in serpentine acid coolers and then stored.

External fuel input, mainly light diesel oil (LDO), is required during start-up and in instances where additional energy is necessary to enhance the temperature of the SO_2 gases. Electricity is used for powering drives of blowers and fans which handle the gases. The material and energy balance of the sulphuric acid plant connected with the zinc smelters is given in Table 16.

Leaching

Leaching of the roasted zinc concentrate (calcine) is next in the smelting operation. Calcine is leached with spent electrolyte, which is sulphuric acid solution containing residual zinc sulphate. The purpose is to selectively dissolve all the zinc present in the calcine and precipitate iron and other accompanying impurities such as arsenic, antimony, silica and germanium. Though actually more

Table 16: Sulphuric Acid Plant : Material and Energy Requirements

Item consumed	Unit	Unit/t of output (acid)	
		HZL-Vizag[1]	HZL-Debari[2]
Concentrate	t	1.8	1.26
Sulphur content of concentrate	per cent	30	30.15
Electricity	kWh	100.5	68.00
LDO	l	19.0	15.16

1/ Based on average of consumption data for 1983-85

2/ Based on average annual consumption data for 1979-83

Source : Study questionnaire responses

complicated, the simple chemical equation given below can be assumed to represent the leaching reaction:

$$ZnO + H_2SO_4 \text{ ---> } ZnSO_4 + H_2O$$

The spent electrolyte and calcine are added in leaching tanks called pachucas, under controlled conditions of acidity to avoid dissolving excess of iron and also to precipitate finally the iron that is contained in the calcine. The process hence gets further classified into neutral and acid leaching.

Neutral leaching action takes place in a series of pachucas which are steel tanks with lead and acid proof brick lining. The process involves reacting calcine with the spent electrolyte by maintaining a pH value of 5 approximately.

Electrically driven stainless steel agitators are located in all the tanks. Live steam is directly injected into the pachucas to maintain temperatures between 55-80^{o}C.

The zinc recovered in the neutral leach is about 85-90 per cent of the total acid soluble zinc present in the calcine. Slurry from the neutral leach section is pumped to hydro-cyclones. Underflow from these cyclones enters the Dorr thickeners.

Flocculating agents are added in the thickeners to help in the settling rate. Sintered zinc oxide from the Residue Treatment Plant is also fed into the circuit. Underflow of the thickeners is passed through filters where solids are separated under vacuum. The filtrate is sent to the purification section while the cake discharged in the form of slurry is transported to the acid leaching section.

The slurry is further leached with excess acid and a low pH of 2.2 -2.8 is maintained in the pachucas. Acid leaching takes more time because a constant pH is required to ensure minimum loss of zinc vis-a-vis re-dissolution of precipitated impurities. Acid leached liquor undergoes filtration; the filtrate is sent back to the neutral leach while the residual cake containing some amount of zinc metal is treated in the residue treatment plant for additional recovery of the metal.

The leaching process described can be carried out either continuously or in batches. The trend is to leach continuously because this requires less equipment, space and labour, and is considered to be better adapted to automatic control. Both continuous and batch leaching procedures are followed in the zinc smelters in India. HZL-Debari practices continuous leaching while the HZL-Vizag smelter is based on the batch process.

Purificaton

The clear overflow obtained from the neutral leaching section is subjected to a series of purification stages. Purification is accomplished largely by additions of zinc dust which precipitates copper, cadmium, cobalt, nickel and other residuals by replacement.

The first stage of purification removes copper, cadmium and nickel by precipitation. Since zinc is placed higher than all these elements in the electromotive series, it displaces these from the sulphates according to the typical reaction:

$$Zn + MSO_4 \text{ ---> } ZnSO_4 + M$$

Table 17: Leaching and Purification : Material and Energy Requirements

Item consumed	Unit	Unit/t of output (cathode)	
		HZL-Vizag[1]	HZL-Debari
Calcine	t	1.9	1.8
Zinc Dust	kg	64.2	72.4
MnO_2	kg	56.7	56.0
Sulphuric Acid	kg	343.0	187.0
Fe Scrap	kg	NA[4]	30.8
Clinker ZnO from Residue Treatment Plant	t	0.196	NA
Electricity	kWh	174	131
LDO	1	58.0	NA
Steam[3]	t	8	14

1/ Based on average of consumption figures for 1983-85

2/ Based on average annual consumption figures for 1979-83

3/ Steam used at pressure of 4-6 kgf/cm^2

4/ Not Available

Source : Study questionnaire responses

where M could be any metal like copper, cadmium, nickel etc.

The cake obtained after the first stage of filtration is conveyed to the cadmium plant for extraction of cadmium. Filtrate from the first stage passes to the second where cobalt is removed by zinc dust along with antimony after heating the solution to 90°C in a spiral heat exchanger.

The third stage of purification is the polishing stage after which the solution is ready to undergo electrolysis.

Energy requirements are mainly in the form of steam for maintaining process parameters and electricity for material and solution handling. LDO is used in the leaching and purification section for steam generation when the waste heat boiler is down. Table 17 gives the combined material and energy requirements for both the leaching and purification processes.

Electrolysis

The electrolytic cell room is a large area containing a multiplicity of tanks, and each tank contains a number of alternate anodes and cathodes through which the zinc-laden zinc sulphate ($ZnSC_4$) solution or electrolyte slowly flows. The cells are equipped with aluminium cathodes and lead ancdes. The purified zinc sulphate undergoes electrolysis and the cell reaction may be represented as:

$$ZnSO_4 + H_2O + 2e \text{ ---> } Zn + H_2SO_4 + 1/2\ O_2$$

Zinc gets deposited on the cathode, and oxygen in combination with manganese in the solution gets deposited as mud on the anode which is periodically removed. The rate of zinc deposition depends on the current density employed in the cell. Comparatively high current density develops considerable heat in the electrolyte. This would require various external cooling systems to maintain temperature within limits. The temperature in the cells is maintained at 42°C and that of the cell feed at 35°C. Electrolyte is essentially recirculated after passing through the series of cells, while a portion of the spent electrolyte is sent back to the leaching plant. Stripping of zinc from the cathodes is done manually in a periodic fashion once the zinc deposit attains a desired thickness.

The electrolysis step is the most energy extensive among all the smelting operations. Table 18 gives the material and energy requirements for the electrolysis section.

Rationally, all energy conservation measures should be directed towards this operation where even a small percentage reduction in process electricity requirements could lead to extensive savings. Various measures for improving cell efficiency--by minimising down time and avoiding short circuiting between anodes, and cathodes headers--are being tried and implemented. Thinning of the lead anode headers has been recommended to minimise possibility of short circuiting. Increasing current density, changing the space between anode and cathode, minor modifications in flow channels, and circulation of solution have been suggested to minimise power consumption [1].

Table 18: Electrolysis Plant : Material and Energy Requirements

Item consumed	Unit	Unit/t of output (zinc cathode)	
		HZL-Vizag 1/	HZL-Debari 2/
Solution from Leaching and Purification Section	m^3	13.7	NA 3/
Electricity	kWh	3907	3826

1/ Based on average of consumption figures for 1983-85

2/ Based on average annual consumption figures for 1979-83

3/ Not Available

Source : Study questionnaire responses

Table 19: Cathode Melting : Material and Energy Requirements

Item consumed	Unit	Unit/t of output (zinc ingot)	
		HZL-Vizag 1/	HZL-Debari 2/
Cathode	t	1.06	1.036
Electricity	kWh	100.7	136.6

1/ Based on average of consumption figures for 1983-85

2/ Based on average annual consumption figures for 1979-83

Source : Study questionnaire responses

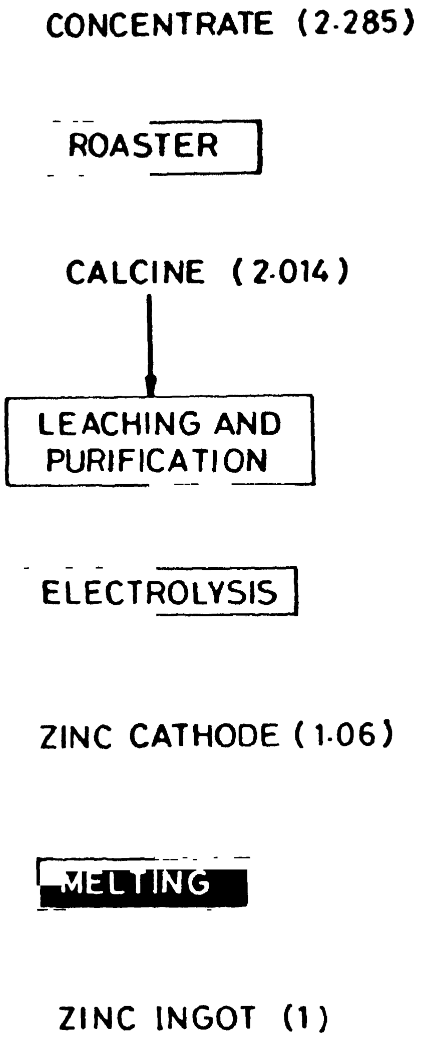

FIG 4 - Material flow for 1 tonne of Zinc Ingot at HZL Smelter - Vizag

Note:
- Percentage of Zinc in concentrate is 52·88
- Metal Recovery $= \frac{1}{0.5288 \times 2.285} = 82.7\%$
- Based on the average of annual consumption figures for the period 1983 - 85.

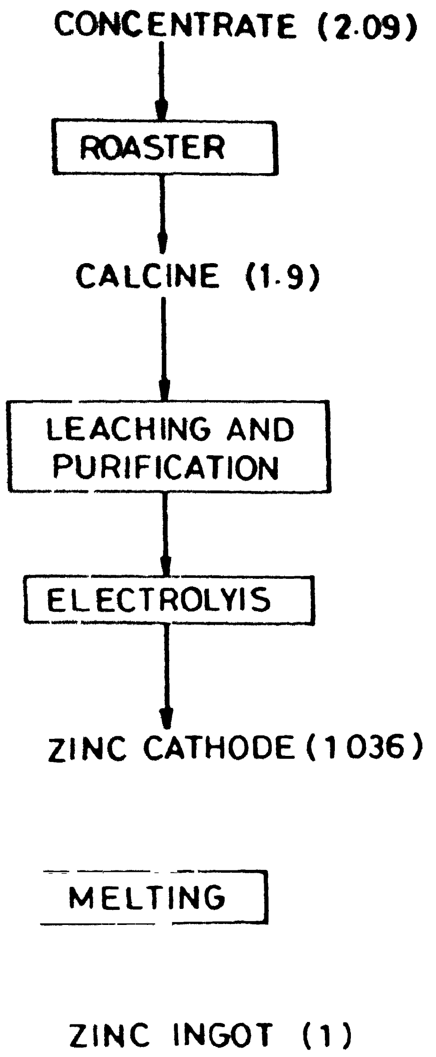

FIG 5 -Material flow for 1 tonne of Zinc Ingot at HZL Smelter-Debari

Note . • Percentage of Zinc in concentrate is 52.1

- Metal Recovery $= \dfrac{1}{0.521 \times 2.09} = 91.8\,\%$
- Based on the average of annual consumption figures for the period 1979-83.

Melting

The stripped zinc cathode sheets are melted in low frequency induction furnaces. Ammonium chloride is used as a flux. The temperature of the furnace is maintained at around 450°C which is sufficient to melt the metal. The metal is then cast into ingots. Melting drosses are recycled either to the roaster if it is oxide dross or recharged to the melting furnace if it is metallic dross. Table 19 gives the energy and material requirements in the zinc melting process.

Residue Treatment Plant

Residue treatment facilities are required to increase extraction of zinc from the ore. The treatment aims at recovering zinc from the filter (Moore) cake obtained in the acid leaching section. The zinc smelters in India use both pyrometallurgical (HZL-Vizag) and hydrometallurgical (HZL-Debari) routes for residue treatment.

Pyrometallurgical Route (Waelz Kiln Process): The process involves fuming of zinc from the residues, by use of an external fuel for the endothermic decomposition of the residue. The sludge is initially dried in a rotary drum drier which uses fuel oil. The dried sludge is then transported to the Waelz kiln.

The Waelz kiln is coke fired. Flow of hot gases in the Waelz kiln is counter current to the charge movement, which allows the gases to be used for charge heating. Zinc present in the residue evaporates from the charge, gets instantly oxidised, and is carried away by the gas stream. The stream is then passed through dust chambers, tubular coolers,and bag filters, and enters the clinker kiln.

Table 20: Residue Treatment Plant, HZL-Vizag : Energy and Material Requirements[1]

Item consumed	Unit	Unit/t of output
Waelz kiln		
Moore Cake	t	3.26[2]
Coke Breeze	t	2.00[2]
Coal Dust	t	0.19[2]
Clinker kiln		
Raw Zinc Oxide	t	1.18[3]
Coal Dust	t	0.21[3]
Fuel Oil	l	84.00[3]
Electricity (Total in Residue treatment plant)	kWh	605

1/ Based on average of consumption figures for 1983-85

2/ Per tonne of raw zinc oxide

3/ Per tonne of clinker

Source : Study questionnaire responses

The clinker kiln is coal and oil fired and operates at a temperature of 950°C. The clinker kiln conditions the recovered raw zinc oxide to enable its processing by electrolysis. Impurities like chlorine, flourine, lead, and cadmium are separated from the zinc oxide. The recovered zinc oxide is then fed back in the leaching circuit. The energy and material consumption of the residue treatment facility located at HZL-Vizag is given in Table 20.

Hydrometallurgical Route (Conversion Process of Outokumpu): The hydrometallurgical route involves a single stage treatment of residue, with the advantage of recovering hitherto unrecovered precious metals in the residue, if present.

The residue from the leaching section is initially subjected to a froth floatation process by which silver rich particles are differentially separated. The tailings from the process, rich in zinc, enter a conversion reactor and are subjected to conversion leaching with hot spent electrolyte and sulphuric acid at a temperature of 95°C. The conversion reactor uses steam for maintaining the desired reaction temperature. The overflow from the reactor, after washing and passing through counter current decantation thickeners and two stage filtration, joins the main neutral solution stream. The sludge from the filters is finally disposed.

Fuel oil supplies heat for the multiple hearth roaster in the silver recovery circuit. Electricity is used to power the drives used for the transportation of residue, slurry etc.

Information on material and energy flow for this section was not available.

COMBINED MATERIAL AND ENERGY BALANCE

To enable the consideration of all energy requirements on the basis of production of one tonne of zinc ingot, the flow of zinc metal is traced back through the various refining processes to give estimates of the concentrates and the ore required. Fig 4 illustrates the material balance flow-sheet for the smelter of HZL-Vizag, and Fig 4 shows the overall material balance of the HZL-Debari smelter.

On the basis of the material flow estimated, the energy requirement in different stages of zinc production was computed. Energy required for mining of ore has been estimated by using the information given in the report by the National Council of Applied Economic Research (1983) since this was not covered by the questionnaire. To convert the different forms of energy to a common physical unit, thermal conversion values given in Appendix 1 were used. As shown in Appendix 1, two cases of electricity conversion have been considered. In the calculations performed for Case 1, the thermal equivalent of electricity has been used; for Case 2, the primary energy equivalent of electricity has been used. This is based on the overall efficiency of electricity generation by public utilities, including energy consumed in auxiliaries and transmission and distribution losses. The consumption of energy in different stages for the HZL smelters considering both the conversion values of electricity is shown in Table 21. Due to unavailability of complete data, the total energy consumption for both the plants has not been given.

Table 21 . Energy Consumption in the Production of Zinc

Process	Unit	Unit/net t of zinc ingot		Gcal/net t of zinc ingot[1/]		Gcal/net tonne of zinc ingot[2/]	
		HZL-Vizag	HZL-Debari	HZL-Vizag	HZL-Debari	HZL-Vizag	HZL-Debari
Mining							
Electricity	kWh	-[5/]	539.00	-	0.464	-	2.318
Beneficiation							
Electricity	kWh	-	861.00	-	0.741	-	3.702
Roasting							
Electricity	kWh	148.00	133.50	0.127	0.115	0.636	0.574
LDO[3/]	t	0.018	0.017	0.180	0.170	0.180	0.170
Steam[4/]	t	2.456	2.246	1.640	1.500	-1.643	-1.503
Sulphuric Acid Plant							
Electricity	kWh	127.00	112.70	0.109	0.097	0.546	0.485
LDO	t	0.020	NA[6/]	0.200	NA	0.200	NA
Leaching and Purification							
Electricity	kWh	183.00	145.00	0.157	0.125	0.787	0.624
Steam	t	2.60	NA	1.710	NA	1.739	NA

Contd .

Table 21 (contd.)

Energy Consumption in the Production of Zinc

Process	Unit	Unit/net t of zinc ingot		Gcal/net t of zinc ingot[1/]		Gcal/net t of zinc ingot[2/]	
		HZL-Vizag	HZL-Debari	HZL-Vizag	HZL-Debari	HZL-Vizag	HZL-Debari
Electrolysis							
Electricity	kWh	4141.00	3988.00	3.561	3.430	17.806	17.148
Melting							
Electricity	kWh	108.00	136.00	0.093	0.117	0.464	0.583
Residue Treatment							
Electricity	kWh	125.00	53.60	0.107	0.046	0.538	0.230
Coke breeze	t	0.533	-	2.665	-	2.665	-
Coal dust	t	0.047	-	0.235	-	0.235	-
FO[3/]	t	0.0147	-	0.147	-	0.147	-
Boiler House							
LDO	t	0.0522	0.0509	0.522	0.509	0.522	0.509
Diesel Generator Sets							
HSD[3/]	t	NA	0.0252	NA	0.252	NA	0.252

Contd .

Table 21 (contd.)

Energy Consumption in the Production of Zinc

Process	Unit	Unit/net t of zinc ingot		Gcal/net t of zinc ingot[1/]		Gcal/net t of zinc ingot[2/]	
		HZL-Vizag	HZL-Debari	HZL-Vizag	HZL-Debari	HZL-Vizag	HZL-Debari
Transport							
HSD/Petrol	t	0.0025	NA	0.025	NA	0.025	NA
Miscellaneous							
Electricity	kWh	628	523	0.540	0.450	2.700	2 249

Note. Conversion Values (1 Gcal = 10^9 calories)

Electricity (thermal equivalent) - 860 x 10^{-6} Gcal/kWh
Electricity (primary energy equivalent) - 4300 x 10^{-6} Gcal/kWh

Fuel Oil	- 10 Gcal/t	Coal Dust	- 5 Gcal/t
LDO	- 10 Gcal/t	Coke Breeze	- 5 Gcal/t
HSD/Petrol	- 10 Gcal/t	Steam	- 0 669 Gcal/t

1/ Electricity converted to equivalent thermal energy
2/ Electricity converted to equivalent primary energy
3/ LDO - Light Diesel Oil
HSD - High Speed Diesel
FO - Fuel Oil
4/ Negative sign since steam is generated in waste heat boiler
5/ Not Applicable
6/ Not Available

Source Study questionnaire responses.p172

4. COMPARISON OF MATERIALS AND ENERGY USE BETWEEN INDIAN AND INTERNATIONAL PLANTS

A comparison of the material and energy consumption figures for Indian primary zinc producers with those of other countries viz., U.S.A. and Australia has been carried out. [1,6].

Tables 22 and 23 give comparison of the energy and material use in Indian and International plants. While comparing the performance of the plants, the following points should be noted:

- The comparison is for energy consumption in the production of one tonne of zinc by the electrolytic process route.
- The Australian ore assays about 18 per cent zinc, 5 per cent lead, 0.5 per cent copper, and very small amounts of gold and silver. All mining is under ground. In comparison, Indian ore extracted by underground mining methods contains between 3.3 - 4.2 per cent of zinc and 0.8 1.5 per cent of lead.
- Overall metal recovery in the Indian zinc smelters is lower than that in the Australian plants.
- Electrical energy consumption for the electrolysis step is the most significant. The differences in the consumption may be attributed to the different current densities employed and other cell structure differences. Most zinc companies are carrying modifications in the cell structures, flow channels, etc., to reduce energy consumption. The current density employed in the Indian plants is 400 amp/m^2, while the average current density in the U.S plants is 700 amp/m^2.

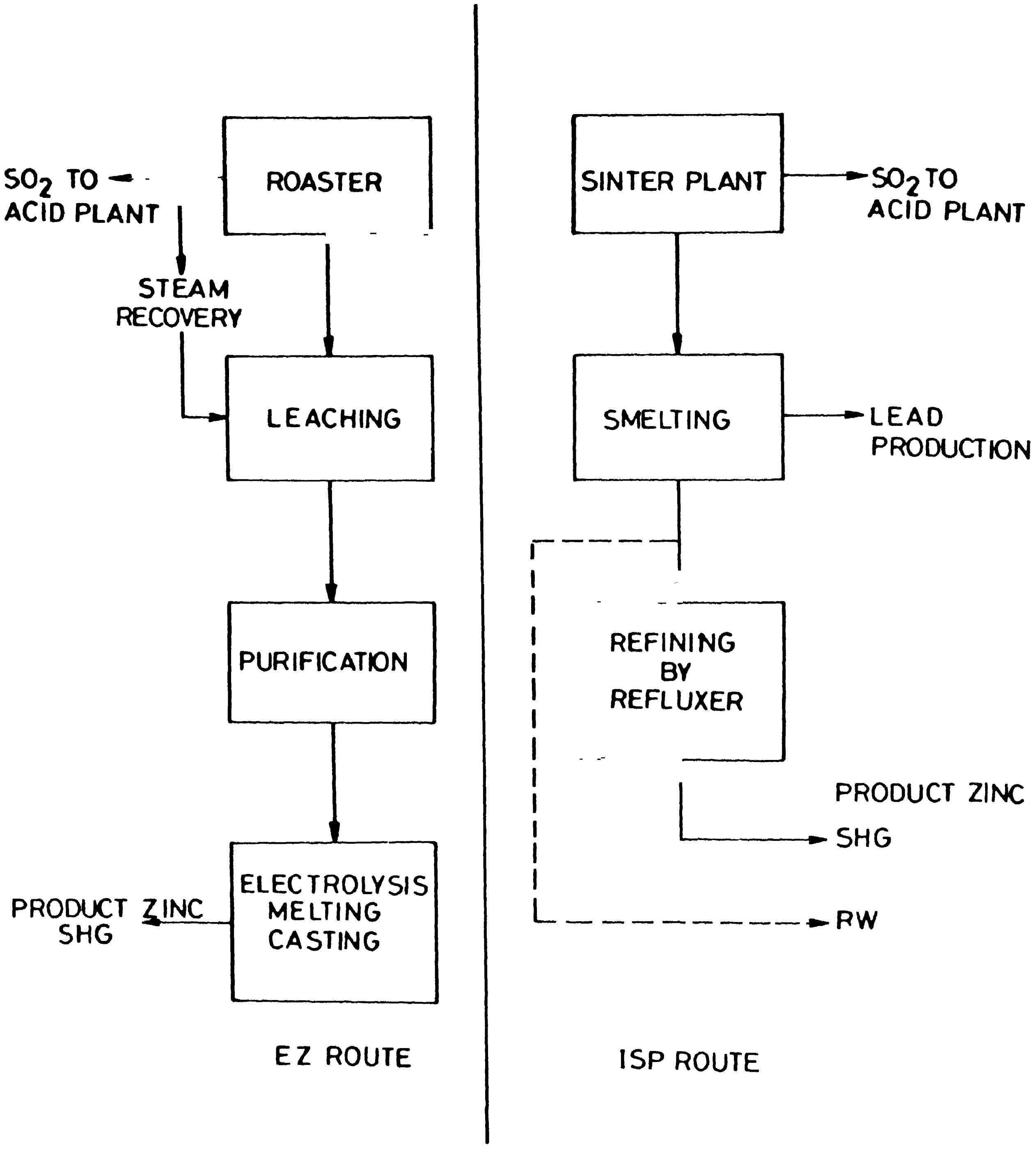

FIG. 6 -Outline Flowsheets for EZ and ISP Routes of Zinc Production

Note: EZ - Electrolytic Zinc
ISP- Imperial Smelting Process
SHG- Special High Grade
PW - Prime Western

Source: Robson, W. Alfred (1980) Energy and Environmental Aspects of the Zinc-Lead Blast Furnace

Table 22: Electrical Energy Use in Indian and International Zinc Plants (per t of zinc ingot)

Process	Unit	India[1/]	United States[2/]	Australia[3/]
Mining	kWh	539.0	407	NA[4/]
Beneficiation (includes crushing and grinding)	kWh	861.0	540.9	NA
Sub Total		1400.0	947.9	1340.0
Leaching and Purification	kWh	164.0	78.0	NA
Electrolysis	kWh	4064.0	3960.0	3578.0
Melting	kWh	122.0	110.0	105.0

1/ Based on average energy consumption figures compiled from study questionnaire responses

2/ Estimated from Battelle Columbus Laboratories

3/ Estimated from Middleton and Patterson

4/ Not Available

Source: 1. Middleton,G.J. and Patterson, I.G., Energy Analysis of Zinc Production, Environmental Studies Working Paper University of Tasmania, Australia, 1977.

2. Battelle Columbus Laboratories, Energy Use Patterns in Metallurgical and Non-metallic Mineral Processing, Phase 4 - Energy Data and Flowsheets, High Priority Commodities, Ohio, 1975.

3. Study questionnaire responses

Table 23:Comparison of Material Consumption in Indian and Australian Zinc Plants

(per t of zinc ingot)

		India		Australia
Input	Unit	Range	Average	Average
Concentrate[1/]	t	2.09-2.28	2.18	1.9
Calcine	t	1.9 -2.01	1.95	NA[2/]
Zinc Cathode	t	1.03-1.06	1.04	1.08

1/ Zinc concentrate is assayed at 52.5 per cent zinc for Indian plants and at 53 per cent for Australian plants

2/ Not Available

Source: 1. Middleton, G.J. and Patterson, I.G., _Energy Analysis of Zinc Production_, Environmental Studies Working Paper, University of Tasmania, Australia, 1977.

2. Study questionnaire responses

Electrical energy consumption in cathode melting is comparable among all the plants.

The Indian and the Australian plants use oil as a direct energy input in the roasting process to raise the temperature of fluid roasters during start-ups and to stabilise the roaster conditions. The plants in the United States, however, use natural gas. Indian plants consume 17 kg (170 Mcal) of LDO while the Australian zinc plant consumes 2 kg of fuel oil (20 Mcal) /t of zinc ingot. The U.S plants consume 1049 ft^3 of natural gas /t of zinc ingot in the roaster. This amounts to approximately 264 Mcal /t of zinc ingot of energy. A possible reason for the higher energy consumption in the Indian plants is the increased number of start-ups due to process interruptions. A large number of interruptions are due to power shortages.

With regard to energy supply, the Indian plants face frequent power cuts which affect stable and optimal operation and lead to higher energy consumption. Besides production loss and higher specific energy consumption, power cuts also lead to increased material consumption.

5. FUTURE DEVELOPMENTS

In the past, the demand for zinc has always outstripped supply. This has forced the country to import zinc to add to local production. To meet around 73 per cent of the demand of zinc by 1992-93, a new lead-zinc smelter based on the pyrometallurgical Imperial Smelting Process (ISP) route is being set up at Chanderiya in Rajasthan. In this chapter, a comparison of the ISP process with the electrolytic zinc (EZ) process has been carried out. Special features of the ISP process, and the factors affecting the suitability of its application are also discussed.

PROCESS ROUTE COMPARISON

Block diagrams of the electrolytic zinc route and the ISP process are depicted in Fig 6.

Both commence with an initial stage for oxidation of the sulphide concentrates. A fluid bed roaster is used for the EZ process, and an updraught sinter machine for the ISP.

Zinc is converted to zinc oxide and SO_2 gas is recovered in both the processes for conversion to sulphuric acid. After this stage the two techniques are different. In the ISP route coke is used as the reducing agent for metal production, whereas electricity is employed for reduction in the EZ route.

To obtain products such as Special High Grade (SHG) zinc, both routes require a purification stage. For the EZ route, very pure zinc sulphate solution is essential. This entails that the purification stage must be carried out prior to the reduction of the metal. In the ISP or the pyrometallurgical route, the process yields Prime Western Grade (PW) zinc. However, depending upon the market demands, the PW zinc can be refined in reflux columns to obtain SHG zinc.

Finally the most significant difference is that in the ISP route, lead is produced simultaneously with zinc, whereas in the EZ process, lead is not produced.

TECHNOLOGY COMPARISON

At present, over 75 per cent of the world's zinc production is by electrolytic process and around 12 per cent by ISP. The remaining is by horizontal and vertical retorts and electro-thermic process. Some features of these technologies are compared below.

Flexibility

The range of raw feed materials which a process can tolerate is an important criterion for assessing its performance. The ISP route, in comparison with the EZ process, operates on a wide range of feed materials for the simultaneous production of zinc and lead. The ore reserves at the new Rampura-Agucha mines are rich multi-mixed (lead and zinc) metal ores with high silica content, which can be processed advantageously through the ISP route.

Metal Recovery

Recovery of zinc from zinc concentrate input in an electrolytic plant is greater than zinc recovery in an ISP plant. The EZ process also produces high grade zinc, superior to what is obtained in an ISP.

However, the ISP route also recovers lead, and the overall metal recovery from multimetal concentrates is higher in the thermal route.

Investment

The EZ plants entail higher investment costs. In comparison, investment in an ISP plant is less than the combined investment cost of separate zinc electrolysis and lead smelting facilities.

Energy Consumption

The major energy input to the EZ process is electricity. The EZ route is a heavy consumer of power. The non-availability as well as the unreliability of supply are significant factors in the operational performance of the plant.

The ISP is a coke based plant. Indigenous coke has very high ash content compared to the coke used hitherto in the ISP. Import of good quality coke, where the ash content does not exceed approximately 10 per cent, may have to be considered to gain additional zinc output.

Comparison of the primary energy consumption reveals that the ISP consumes marginally less energy. Data on the primary energy requirement for production of one t of zinc by the ISP and EZ routes [12] are given in Tables 24 and 25. To ensure a common basis for the comparison, the energy requirement for the refluxing process for production of SHG zinc in the ISP route is also considered. Other assumptions made for the comparison are indicated as foot-notes in the tables.

Table 24: Specific Energy Consumption - Electrolytic Zinc Route

Products: 1 t SHG zinc, 1.78 t H_2SO_4 (net)

Process Stage	Specific Consumption Electricity (kWh)	 Oil/gas (kg)	 Energy (GJ)
Roasting	120		0.43
Leaching and Purification	190		0.68
Electrolysis	3580		12.9
Melting and Casting	134		0.48
Steam Plant		33.7	1.35
Acid Plant	240		0.86
Miscellaneous	70		0.25
Total	4334	33.7	
GJ equivalent	15.6[1]	1.35[2]	16.95
Concentrates (2.0 t)			8.7
Secondary energy subtotal			25.65
Power station thermal losses @ 67 per cent			31.7
Total primary energy requirement/t zinc			57.35

[1] 1 kWh = 3.6 MJ

[2] 1 kg oil = 40.0 MJ

Table 25: Specific Energy Consumption -Imperial Smelting Process Route

Products: 1 t SHG zinc, 0.5 t lead, 2 t H_2SO_4

	Specific Consumption			
Unit Process	Electricity (kWh)	Coke (kg)	Oil (kg)	Energy (GJ)
Concentrate handling	12	-	-	0.04
Sinter roast	145	-	20	1.32
Furnace	368	1030	36	31.66
Cadmium	-	-	1.4	0.06
Acid	150	-	-	0.54
Refluxing	22	-	160	6.48
Total	697	1030	217.4	
GJ equivalent	2.51[1]	28.9[2]	8.70[3]	40.1
High grade concentrates:				
1.76 t zinc concentrates				7.7
0.62 t lead concentrates				1.2
Secondary energy subtotal				49.0
Power station thermal losses @ 67 per cent				5.0
Coke oven losses @ 15.5 per cent				5.3
Total primary energy requirement without credit for lead				59.3
Credit for 0.5 t lead (blast furnace route)				(8.0)
Total net primary energy requirement/t zinc				51.3

1/ 1 kWh = 3.6 MJ

2/ 1 kg coke = 28.0 MJ

3/ 1 kg oil = 40.0 MJ

APPENDIX 1

THERMAL CONVERSION VALUES OF DIFFERENT FORMS OF ENERGY

Energy Form	Unit	Thermal Conversion Values Gcal[1/]
a. Electricity (Case I)	kWh	860×10^{-6}
b. Electricity (Case II)[2/]	kWh	4300×10^{-6}
c. Light Diesel Oil (LDO)[3/]	t	10.0
d. High Speed Diesel (HSD)[3/]	t	10.0
e. Fuel Oil (FO)[4/]	t	10.0
f. Low Sulphur Heavy Stock (LSHS)[4/]	t	10.0
g. Coal/Coke	t	5.0

1/ 1 Gcal = 10^9 calories

2/ The overall efficiency of electricity generation by public utilities has been taken as 20 per cent, accounting for auxiliary consumption and transmission and distribution losses

3/ Specific gravity of LDO/HSD has been taken as 0.85

4/ Specific gravity of FO/LSHS has been taken as 0.98

REFERENCES

(1) Battelle Columbus Laboratories, Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing, Phase 4 – Energy Data and Flowsheets, High Priority Commodities, Ohio 1975a

(2) Battelle Columbus Laboratories, Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing, Phase 8 – Opportunities to Improve Energy Efficiency in the Production of High-Priority Commodities without Major Process Changes, Ohio,1975b.

(3) Bureau of Mines, Ministry of Steel and Mines, Government of India, Directory of Mineral Consumers in India, Vol. 2, Nagpur, 1983.

(4) Department of Mines, Ministry of Steel and Mines, Government of India, Annual Report - 1983-84, New Delhi, 1984.

(5) Kapur, R.P., "Development of Lead-Zinc Mining Industry in India", Urja, November, New Delhi, 1984, pp. 393-397.

(6) Middleton, G.J. and Patterson, I.G., Energy Analysis of Zinc Production, Environmental Studies Working Paper, University of Tasmania, Australia, 1977.

(7) National Council of Applied Economic Research , Forward and Backward Linkages in Non Ferrous Metals and Coal and Lignite Sectors, Vol. 1 – Lead, Zinc and Cadmium, New Delhi, 1983.

(8) Parvathisem, P., "The Electrolytic Zinc Plant of HZL at Vizag, "Proceedings of the Seminar on Lead, Zinc and Cadmium – Retrospect and Prospect, November 18-21, New Delhi, 1981.

(9) Planning Commission, Government of India, Seventh Five Year Plan Report, New Delhi, 1985.

(10)Pugazhenthy, L., "Status of Secondary Zinc Industry in India", Seminar on Conservation of Non-Ferrous Metals and Energy by Recirculation, August 13-14, New Delhi,1985 pp. 3.5-3.16.

(11)Solanki, S. and Vakil Singh. "The Electrolytic Zinc Plant of HZL at Debari and its Development", Proceedings of the Seminar on Lead, Zinc and Cadmium – Retrospect and Prospect, November 18-21, New Delhi, 1981.

(12)Robson, A.W., 'Energy and Environmental Aspects of the Zinc -Lead Blast Furnace' presented at the Third Energy Conservation Convention, September 9-12, 1980, Indianapolis..op